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ical, best-appearing 3- and occasional 3 + -lobed grains of diploid forms; 40 per cent. or fewer, good-appearing. Moderate amount of seed obtained from selfed flowers. Seeds large, germinate quickly. Plant will probably have 28 chromosomes, particularly if an offspring of a 14- or a 28-chromosome form, selfed, or of a 14 x 28. If the product of 15 x 28, it may have 28, 29, or even 30, chromosomes, I. Forms which are approximately, but not precisely, tetraploid, may be wholly male-sterile.

These statements are not intended to imply that all diploid, triploid and tetraploid forms have the characters enumerated above, but merely that forms displaying certain pollen conditions and vegetative characters will *probably* (by no means certainly) have the number of chromosomes specified.

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ON THE PERIODIC SHOREWARD MIGRATIONS OF TROPICAL NUDIBRANCHS¹

MANY northern gastropods, including nudibranchs, are well known to exhibit the habit of congregating in shallow water along the shore at their time of breeding. This has been commonly interpreted as the result of migration from deeper water at the approach of the egg-laying season. Certain species, at any event, are from time to time found in great quantity at shore stations which they do not frequent at other periods, and field observations have apparently established beyond a doubt that this inshore appearance is closely connected with mating and oviposition. The migration into shallow water, or other means which accomplishes the shallow-water flocking in these cases, may be regarded as a device which insures the concentration of individuals within a relatively small area, thus tending to make more certain the chances of pairing in a large number of instances, as well as a method of determining favorable conditions for larval development.

Collectors of nudibranchs who have worked in tropical waters have also reported cases which at first sight seem to afford additional examples of the coincidence of the spawning period with appearance in great numbers in the littoral zone (*e. g.*, Crossland, quoted by Eliot, 1904, p. 87). While engaged in working along the shore during a period of some days or weeks, it is

¹ Contributions from the Bermuda Biological Station for Research, No. 59.

noticed that a certain species of nudibranch, until then found sparsely, if at all, suddenly begins to occur in abundance. It is also observed that at this time these nudibranchs are depositing eggs in the field, or that they pair readily and lay egg strings when kept in aquaria. The inference which has been drawn in such cases, namely, that the appearance in shoal water is in some way intimately related to the mating process, seems legitimate enough.

But I have observed at Bermuda certain facts regarding the normal migrations of a member of the typically tropical genus *Chromodoris* which, it seems to me, cast considerable doubt on the theory that this species, *C. zebra* Heilprin, moves into shallow water for the purposes of mating and egg deposition. The facts in this case, so far as they have been observed, are briefly as follows:

It was necessary to obtain considerable numbers of *C. zebra* for use in experimental work (Crozier, 1916^a, 1916^b); consequently collections were made at short intervals (every day during some months) over the period from August, 1915, to October, 1916. I had had occasion, also, to note the occurrence of this species in the summers of 1913 and 1914. In June, and during the early part of July, *Chromodoris* was found in great abundance upon the "eel grass" in certain tidal "creeks" (Fairyland Creek, Millbrook Creek). Subsequently, in the last two weeks of July and in August, they became very scarce in such places, although a few could almost always be discovered by careful searching. At other times of the year a supply of the animals was obtained on hard, open bottoms in somewhat deeper water (1 to 2 fathoms, at low tide), in places where, I am certain, they would never have been seen during ordinary shore collecting. Occasionally, however, as was noted particularly in December, 1915, *Chromodoris* was abundant along the rocky shores of smaller islands, ranging well up to low-water level.

It seems clear enough that in *Chromodoris zebra* there undoubtedly does occur from time to time a movement of numbers of individuals toward the shore. But there are several facts which sharply contradict the view that this migration is connected with reproduction. The nudibranchs pair in the laboratory and lay strings of fertile eggs at all seasons of the year (cf. also Smallwood, 1910), and not merely at the times when

they are abundant near low-water level. Moreover, I have obtained the egg masses in dredgings at every season of the year; hence we may regard the fact of egg laying at all seasons under laboratory conditions as of significance in this connection. The eggs, which are quite characteristic in appearance, and hence easily identified, have been collected in depths of eight fathoms and more. Large individuals of *C. zebra* are likewise not uncommon at these depths; in fact, the first ones to be described were dredged from ten fathoms in Harrington Sound (Heilprin, 1889, p. 187). A further point of considerable significance is found in the fact that these nudibranchs, unlike *Elysia* and certain other species, do not appear to deposit any egg masses upon the "eel grass" on which the animals occur in such great numbers throughout the early summer. The egg strings found in the field are invariably attached to rocks, or to the shells of *Arca noe*, the "mussel" with which the adults are frequently associated. The gelatinous egg-ribbons (cf. Smallwood, 1910) are quite large, measuring usually 120 to 150 mm. long by 15 to 17 mm. broad, and are much too heavy to be supported by a blade of "eel grass," as can readily be determined by trial. It is only rarely that an egg mass has been obtained in shore collecting.

The migration of *C. zebra* into shallow water cannot, then, be directly connected with reproductive activities. Since, in the laboratory at least, they deposit eggs usually within twenty-four hours after pairing, it does not seem to me probable that these nudibranchs pair to any great extent during the time which they appear to spend in the tidal "creeks"—no eggs, as stated, having been collected from among the "eel grass," nor were any ever obtained on the muddy bottoms of these "creeks." *Chromodoris* seems to require a firm, hard substratum for the attachment of its egg-ribbon. If individuals obtained in quite shallow situations are kept singly in aquaria they sometimes deposit after several days fragments of egg-jelly containing several dozen unfertilized eggs, while they almost invariably pair readily when given the opportunity. Nevertheless, it should be stated that the nudibranchs usually do not occur singly, two or three being commonly found within a space of several square meters even when the total number of individuals in a given area is small; and I am well aware that laboratory findings with regard to breeding habits are liable to be misleading. The established

fact of egg production throughout the year in deep water is, however, good evidence that the periodic (or intermittent) abundance of this nudibranch in shoal situations can have little if any relation to oviposition.

It might at first be suspected that the periodic shoreward movement represents the phylogenetic persistence of a well-defined habit possessed by not distantly related northern species. From this standpoint, reproductive functions in *C. zebra* might be conceived of as having become dissociated from the habit of migratory periodicity, since in warmer seas, where the seasonal alteration in physical conditions is reduced to a minimum, it is well known (cf., for example, Semper, 1881, p. 135) that many forms have no specially restricted time for breeding. However attractive such a speculation may appear, it is eminently more satisfactory to regard these periodic littoral appearances of tropical nudibranchs as being controlled by definite physical influences in each individual case. Such directing causes would not necessarily be always the same for each periodic occurrence of the animals in shallow water. Although shoreward migration and egg laying are closely connected in northern forms, it is still probable that physical circumstances in the sea immediately control the migrations even in this instance also.

I have purposely refrained until now from discussing certain minor fluctuations in the littoral abundance of *Chromodoris* which are, nevertheless, important in connection with the idea that the supposed "migration" at certain times into very shallow water is, after all, only the unrestricted expression of a tendency to upward movement—negative geotropism. It has been mentioned that during the greater part of the year *Chromodoris* was collected in 1 to 2 fathoms. But after storms of some severity they were to be had only in much deeper water. The nudibranchs undoubtedly move into deep, quiet places when the surface is greatly disturbed. Just what their behavior is under these circumstances can not be stated from direct observation, for obvious reasons; and for several days, or even for a week after a severe blow, the water in the sounds and bays remains so roily that it is impossible to see the bottom. But I have frequently observed individuals creeping up from deep water after the sea has become quiet and transparent. As regards the bearing of these facts upon the major flocking into the littoral zone, which occurs in early summer, it is to be noted that the mere

continuance of quiet, still weather is not enough to determine the abundance of *Chromodoris* in the tidal "creeks," since they disappear for the most part before the calm summer season is half over. The occurrence of individuals in deep water, together with field observations of specimens which were engaged in creeping downward on the sloping sides of rocks and reefs, leads me to doubt very much that any form of geotropic irritability exerts a preponderant control over the normal behavior of these animals. My observations strongly suggest, however, that there does occur to some extent (in appropriate places) a diurnal vertical movement of *Chromodoris*, which is directly determined by the positive phototropism of these nudibranchs.²

Specimens of the species known as *Chromodoris roseapicta* Verrill (there is some doubt that it is really a *Chromodoris*) have been found in littoral locations, only in the summer time, but this type is not sufficiently abundant to make possible a testing out of ideas concerning its migratory movements.

The point which I wish to emphasize most is the uncertain nature of conclusions having reference to the normal behavior of animals inhabiting the warmer seas on the basis of comparisons with superficial features of the movements of their relatives in colder waters. In the case of *Chromodoris zebra*, it seems to me definitely established that the periodic flocking of individuals into very shallow water has no immediate connection with reproduction.

On Jan. 10th, 1917, I found that *C. zebra* was crowding in great numbers into the entrance of Fairyland Creek. During the next few days they became very abundant indeed, so that on one occasion 230 of them were picked up in less than an hour's collecting. On Jan. 12 I began to find egg masses attached to certain sponges, matted algæ, mangrove roots, and sundry mooring stakes in the "creek." I had not before found any in this place, as stated above. The nudibranchs were observed in copulation, and great numbers of egg-masses were found. The attachment of the egg-masses was most frequently to some firm object. Within the week Jan. 10-17 they began to disappear, and after a fairly severe storm which came at that time very few were obtainable in the "creek." This occurrence seems to form a good

²I am anticipating here the statement of certain facts regarding the responses of *C. zebra* which were established in this laboratory several years ago by Dr. L. B. Arey (cf. also Crozier, 1916°).

instance of shoreward movement coupled with reproductive activity, but the fact remains that the nudibranchs do breed abundantly at other times and in much deeper water.

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